

Behavioral and Environmental Determinants of Reproductive Success in Traditional Moroccan Berber Groups

E. CROGNIER

UPR 221 du C.N.R.S., Pavillon de Lanfant,
13100 Aix-en-Provence, France

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ABSTRACT The reproductive histories of women aged 45–70 years from a homogeneous Berber population of South Morocco were sampled from three contrasting environments: a small town ($n = 75$), villages in the lowlands ($n = 217$), and villages in the highlands ($n = 128$). The main reproductive variables oppose the relatively better conditions of fertile life in the lowlands to the more hostile ones in the highlands. Path analysis confirms this difference through reproductive behaviors and suggests the existence of mechanisms for controlling family size in town and in the rural lowlands, but not in the highlands. The estimates of survival function show significant differences among the three groups, the conditions for survival in the highlands being clearly less favorable. Rank tests of the association of survival data with several covariates indicate the association of survival data with vaccinations and with conditions of delivery. In spite of the lower rate of offspring survival, the highlander group would demonstrate a higher overall number of children reaching reproductive maturity, thanks to an extended reproductive span.

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Reproductive success within a breeding unit should theoretically be equated with the number of “successful offspring” (Jacquard *in* Gomila, 1975; Sawchuk, 1980)—i.e., the number of offspring who themselves have progeny, considering that unfertile ones and those who die before reproductive age do not participate in the transmission of parental genes. In human populations, however, reproductive success is commonly estimated as the number of children having reached reproductive maturity. Following Howard (1979), Arnold and Wade (1984a), and Brown (1988), lifetime reproductive success is often partitioned into evaluations of survival between birth and reproductive age, of reproductive life span, of average fecundity per year of reproductive life span, and of offspring survival between birth and reproductive age (Brown, 1988).

The growing interest in the study of variation in reproductive success in human groups owes much to the idea that its expression is principally dependent on individual or social strategies evolved to maximize it (Chagnon and Irons, 1979; Hill, 1984; Clutton-Brock, 1988; Betzig, 1988; Borgheroff Mulder, 1988). Several studies have already provided quantitative estimates of its expression (Chagnon, 1979; Irons, 1979; Driver, 1981; Pennington and Harpending, 1988; Borgerhoff Mulder, 1988). The present work is an attempt to evaluate variation in female reproductive success of geographical groups of a single Berber population of Morocco, following previous work suggesting

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that fluctuations of its reproductive pattern would mainly express behavioral adjustments related to environmental differences (Crognier et al., 1992, 1993; Crognier, 1993).

MATERIALS AND METHODS

In 1984, a survey involving 1,450 households of the "circle" of Amizmiz, an administrative subdivision of the province of Marrakesh, gathered information about socioeconomic conditions, cultural variables, and medical care. At the same time, the reproductive history of each woman in the household was traced back by means of familial interviews, including her age at menarche, at first marriage, and at menopause; the waiting time to first birth and her successive pregnancies with their outcomes; the child's sex; the conditions of parturition; the duration of breastfeeding; the child's present age or age at death, the cause of death, and the possible use of contraceptives. This survey evenly covered the lowlands of the area up to 1,300 m, and included the small town of Amizmiz, as well as purely rural areas.

In 1986–1987, a second season of field work provided data about communities settled at high altitude on the ridge of the High Atlas, of far more difficult access. Nine villages scattered in the valley of Azgour (2,000–2,300 m), exhaustively investigated, yielded 607 records.

The overall sampling should be representative of life conditions and of reproductive behaviors in this homogeneous Berber-speaking area. Three subsamples are represented in the present work: the rural and urban samples in the lowlands and the rural sample in the highlands.

As most data refer to personal reproductive history, a precise chronology of events ought to be known. Unfortunately, there is only a loose recording of demographic events at the administrative level, and most information concerning ages and dates of miscarriages or early infant deaths depends on family memory. However, caution was taken through cross-interrogations to obtain as good and coherent information as possible.

Previous results of a multiple regression of fertility on several regressors, calculated over the general population, and on the three

samples (Crognier et al., 1992), have shown that a small group of them, including age at marriage, waiting time to first birth, interlive-birth intervals, infant mortality rate, and effective lactation time, account for 45% of the variance in fertility.

The causal importance of these variables on the number of live births a woman can experience throughout her fertile life, as well as on factors influencing the ratio between the number of live born and of offspring surviving until reproductive maturity (here considered to be the age of 15 years for both sexes), is analyzed from this starting point. In this perspective, subsamples of women aged 45–69 years, in the postreproductive period or close to it, were selected from the general survey, in the rural plain ($n = 217$), in the town of Amizmiz ($n = 75$), and in the rural highlands ($n = 128$).

RESULTS

Main reproductive characteristics

Fertility is high in this area. Table 1 shows that women having completed their reproductive life experienced a mean of seven to nine pregnancies resulting in seven to eight livebirths. This is the consequence of an early age at marriage, a long effective reproductive span, and rather short interpregnancy intervals.

Though variations occur, they do not clearly distinguish the reproductive behavior of any subgroup. It is worth noting, however, that the much longer reproductive span of highlanders, as well as their high "time lost for reproduction" (a synthetic variable estimating the relative failure in reproductive effort, by summing for each woman the ages at death of offspring up to 15 years, starting from conception and including prenatal as well as postnatal deaths), is more than twice that of the two other groups. Hence, there is probably much heavier environmental pressure on reproduction in the highlands.

The overall differences in reproductive patterns appraised from subsamples of postmenopausal women (Table 2) agree with previous results from the whole population (Crognier et al., 1992). They show differences in fertility tempo, which are clearly

TABLE 1. Main reproductive parameters in the three groups: means \pm SD

Variables	Town	Lowlands	Highlands
Mean women's age (years)	52.7 (6.0)	54.7 (6.7)	50.3 (4.6)
Mean age at marriage (years)	17.4 (3.0)	18.8 (3.5)	17.4 (3.2)
Mean reproductive span (years)	18.6 (6.1)	18.5 (7.1)	21.0 (5.9)
Mean no. pregnancies	8.5 (3.8)	7.4 (3.5)	8.4 (3.3)
Mean interpregnancy intervals (months)	28.6 (22.0)	32.9 (19.5)	32.1 (22.5)
Mean no. live births	7.9 (3.9)	7.0 (3.5)	8.0 (3.2)
Mean inter-live birth interval (months)	40.5 (10.2)	44.2 (10.1)	48.4 (11.0)
Mean breastfeeding extent (months)	14.8 (8.1)	17.2 (6.5)	15.5 (8.5)
Mean cumulative breastfeeding (months)	102.0 (64.2)	100.1 (61.4)	122.3 (61.3)
Mean reproductive time lost (days)	116.4 (21.5)	86.5 (23.8)	295.5 (16.3)

TABLE 2. Means (\pm SD) of mothers' ages at successive live births

Samples	Parity							
	1	2	3	4	5	6	7	8
Town	19.21 (3.4)	24.04 (6.5)	27.06 (6.5)	29.07 (5.3)	31.20 (5.5)	33.71 (5.6)	34.50 (4.4)	36.06 (4.2)
Lowlands	20.78 (3.9)	26.20 (5.6)	29.90 (6.2)	32.17 (6.3)	34.52 (5.9)	36.91 (6.1)	39.30 (6.6)	40.03 (5.3)
Highlands	19.24 (3.3)	25.79 (4.7)	29.57 (5.6)	32.43 (5.5)	35.81 (5.5)	37.96 (5.2)	40.29 (5.7)	42.04 (5.9)

apparent when mean ages at successive parity levels are computed. Town dwellers reach their eighth live birth at the youngest age, followed by women from rural lowlands, who start reproduction later. Highlanders come to this stage later in age, notwithstanding an early start of reproduction. As shown in Table 1, longer birth intervals are responsible for their slower tempo.

On biological grounds, the number of live births (NLB, Table 3) in a woman's reproductive life is determined by a small set of proximate variables (Bongaarts and Potter, 1983). One such variable is *the span of reproductive life* (SRL), whose variations express those of its two bounds: age at marriage (AMA) and menopause or voluntary cessation or procreation. Only the first bound is culturally set, though in the Berber area another cultural consideration—namely, becoming a grandmother—would commonly induce women to terminate their own SRLs (Naber, 1989).

A second proximate variable is *the sum*

TABLE 3. Variables utilized in the study of reproductive characteristics

AMA: Age at marriage (in years)
ENC: "Effective number of children" = number of children reaching their 15th birthday
IBI: Mean inter-live birth interval (in months)
NLB: Number of live births
NVD: Number of visits to dispensaries or medical centers during the last year
SRL: Span of reproductive life = interval between marriage and last birth (in years)
TLR: "Time lost for reproduction" = sum of offspring's ages at death from conception to 15 years, including prenatal and postnatal deaths (in months)
TLT: "Total lactation time" = total amount of months of breastfeeding in a woman's reproductive life

of intervals between live births (IBI). This includes three constituents: the period of fecundability prior to pregnancy, the length of pregnancy itself, and the length of postpartum infecundability. This variable is also eventually increased by fetal losses. Of its three constituents, the *period of fecundability prior to pregnancy* is not precisely known,

TABLE 4. *Intercorrelations among the variables assumed to determine the number of offspring in the three samples*

	NVD	TLR	AMA	IBI	SRL	NLB	ENC
Town							
TLT	0.170	0.167	-.194	0.613	0.673	0.723	0.630
NVD	—	-.332	0.067	0.139	0.157	0.161	0.249
TLR	—	—	-.199	0.353	0.219	0.265	-.021
AMA	—	—	—	-.281	-.294	-.132	-.266
IBI	—	—	—	—	0.768	0.656	0.545
SRL	—	—	—	—	—	0.741	0.548
NLB	—	—	—	—	—	—	0.700
Lowlands							
TLT	0.139	0.346	-.137	0.577	0.447	0.691	0.615
NVD	—	0.002	0.334	0.090	0.017	-.008	-.044
TLR	—	—	-.021	0.398	0.269	0.575	0.151
AMA	—	—	—	-.064	-.171	-.099	-.181
IBI	—	—	—	—	0.893	0.752	0.566
SRL	—	—	—	—	—	0.725	0.478
NLB	—	—	—	—	—	—	0.637
Highlands							
TLT	0.035	0.453	-.174	0.582	0.400	0.731	0.511
NVD	—	0.089	-.167	-.043	-.207	-.055	0.073
TLR	—	—	-.115	0.546	0.047	0.697	0.284
AMA	—	—	—	-.361	-.208	-.162	-.236
IBI	—	—	—	—	0.775	0.758	0.439
SRL	—	—	—	—	—	0.575	0.092
NLB	—	—	—	—	—	—	0.579

but there are no reasons to suspect contrasts within the Berber area. Variations would therefore express differences in pathologies affecting fecundity, especially those leading to sterility. The main variations in *length of pregnancy* are caused by spontaneous abortions. The extent of *post-partum infecundability* is principally associated with breastfeeding, whose protracting effect on amenorrhea is statistically ascertained. The occurrence of medical contraception is unlikely, insofar as the diffusion of contraceptives in the area was quite recent at the time of the survey.

Though the customs about duration of breastfeeding are not expected to vary between these samples, they may however result in group differences (as seen in Table 1), in particular through the influence of differing rates of infant morbidity according to the environment. The IBI in a woman's fertile life would therefore vary in relation to two main parameters: the sum of lactation time (TLT) and that of time lost for reproduction (TLR). The latter variable is indeed partially dependent on the level of medical assistance, here indirectly estimated through the annual number of visits to dispensaries (NVD).

Path analysis (Li, 1981) was applied to the correlation matrices in Table 4 for identi-

fying the best particular arrangement of causal determinants of NLB and of the "effective number of children" reaching their 15th birthday (ENC) in each environment. TLR was converted to logarithms before the correlation matrices were computed.

Differences in reproductive behavior

In the model of the variables considered, ENC results from a three-stage process (Fig. 1):

1. The determination of inter-live-birth intervals, affected by three causal variables: AMA, TLT, and TLR (itself influenced by NVD).
2. The combination of IBI and SRL to give the NLB.
3. The combination of NLB and TLR to determine ENC.

In the first stage, discrepancies appear between groups in the respective influence of variables (Table 5). In town, the degree of determination of IBI by TLR, TLT, and AMA reaches 45% of its variance, of which 30% is assumed by the direct influence of TLT. In the rural lowlands, only 38% of variance in IBI is explained by the three variables, TLT being still the salient direct determinant with 25% of it (in both cases, TLT as direct

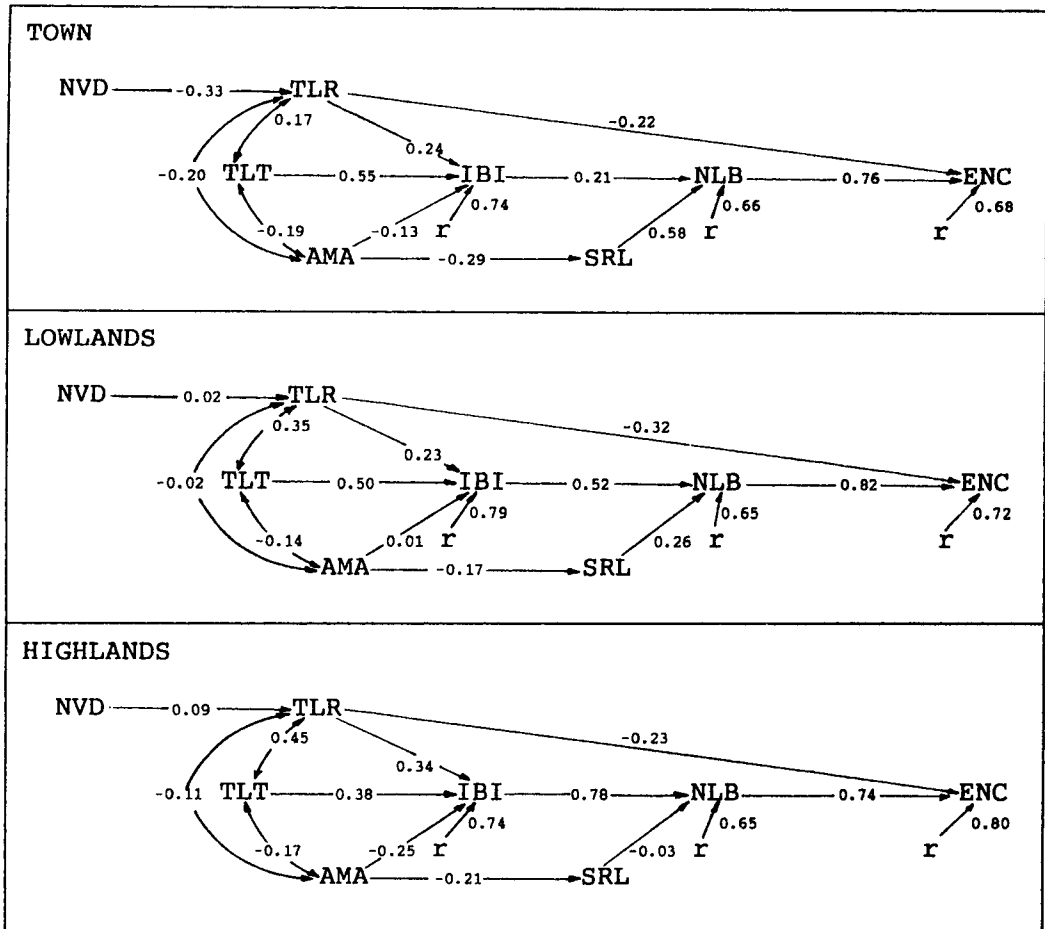


Fig. 1. Path diagrams of factors related to the effective number of children >15 years (ENC). Factors distinguished are number of visits to dispensary (NVD), time lost for reproduction (TLR), total lactation time (TLT), age at first marriage (AMA), intervals between live births (IBI), span of reproductive life (SRL), and number of life births (NLB).

causal agent assumes 66% of the amount of variance explained by the three variables). In the highlands, the situation appears different: as in town, these variables determine 45% of variance in IBI, but their respective weights as direct causal factors are more similar and half of the total determination is related to their combined influences.

The order of causes in the variation of inter-live birth intervals therefore opposes the town and lowland groups to the highland group. In the former, the extent of lactation is the principal regulator, while the latter must cope with higher offspring mortality,

which drives a significant part of variance in IBI.

The effect of health care facilities, indicated from the relation between NVD and TLR, is perceptible only in town. It is indirect evidence of the limitations of efficacy of the sanitary network in rural areas.

In spite of the homogeneity of determination of NLB by IBI and SRL in the three environments (part of the variance explained = 57–58%), the relative contributions of these variables differ, with a clear contrast between rural and urban people.

In town, the leading variable is the SRL

TABLE 5. Degrees of determination by causal variables¹

Determination:	Direct	Combined	Total	Unexplained
Town				
IBI	TLR = .056 TLT = .301			
	AMA = .016	.083	.456	.545
NLB	IBI = .045 SRL = .334			
	NLB = .576	.181	.567	.433
ENC	TLR = .049	-.089	.536	.464
Lowlands				
IBI	TLR = .051 TLT = .248			
	AMA = .000	.077	.376	.624
NLB	IBI = .266 SRL = .070			
	NLB = .676	.244	.580	.420
ENC	TLR = .104	-.306	.474	.526
Highlands				
IBI	TLR = .118 TLT = .146			
	AMA = .065	.123	.452	.548
NLB	IBI = .615 SRL = .001			
	NLB = .549	-.041	.575	.425
ENC	TLR = .054	-.240	.363	.637

¹TLR = time lost for reproduction; TLT = total lactation time; SRL = span of reproductive life; IBI = the inter-live birth intervals; NLB = the number of live-births; ENC = the effective number of children; AMA, age at first marriage.

(33%). Compared with the other areas, the shorter intervals between births and the similar number of live births observed in town (Table 1) suggest the presence of a terminal control of fertility, which limits procreation when family size is optimum. The higher mean interval between last live birth and menopause in town (13.3 years) than in rural areas (11.1 in lowlands and 10.3 in highlands) supports this interpretation.

In rural areas, the main determinant of NLB is variation in intervals between births. It is important in the highlands (61% of variance in NLB), where it includes a high contribution from reproductive failures (TLR assumes as a direct cause 7% of the variance of NLB, while it assumes only 0.3% and 1.4% of it in town and lowlands, respectively). This characteristic, added to the large extent of SRL and to the high level of NLB (Table 1), makes improbable the existence of a planned strategy of birth regulation in the highlands.

The situation appears quite different in the lowlands, although variation in birth intervals is also the principal determinant of the variance in NLB (27%). Here TLR has little influence on IBI, and TLT is almost its only determinant. This suggests a voluntary

determination of the length of intervals by protraction of lactational amenorrhea. Again in contrast with the highland group, SRL is a weak determinant of NLB. SRL in the rural plain is characterized by a later mean age at marriage but not by extension of natality in older ages.

Finally, the part of variance in the number of offspring effectively reaching their 15th birthday (ENC), assumed by what should be its two main determinants, i.e., NLB and TLR, ranges from 54% in town to 47% in lowlands and 36% in highlands. NLB takes the main part of it in each environment. In the rural lowlands, however, the direct determination of ENC by TLR is double of that found in other areas. The negative effect of TLR on ENC is also emphasized in the two rural groups in the path showing joint influences of NLB and TLR.

Variation in reproductive success

The path analysis would suggest that the reproductive behavior of two of the samples (town and lowlands), which are likely to control their number of live births, is different from that of the highlands which are not. Taking into account the preeminent importance of parental care for offspring survival until reproductive maturity (Harpending et al., 1990), maximization of reproductive success in the first two groups should theoretically reflect enhancement of children's survival subsequent either to better environmental conditions or to increased parental care or to both characteristics.

In that perspective, survival functions were estimated over all live born children within each sample by means of the product-limit method derived by Kaplan and Meier (1958). The hypothesis of homogeneity of the survival function across the three samples was rejected both by a log-rank test and by a Wilcoxon test (Table 6).

Highlanders are different. Their mortality remains high between the first and second year of life (Fig. 2, Table 6). There is no doubt that environmental conditions are more adverse at higher altitudes: in particular there is a higher incidence of infectious diseases occurring late in the first year of life (Baudot, 1992). This environmental difference in life conditions, more than undetected variation

TABLE 6. *Survival data and test of homogeneity of survival estimates within the three groups and association of survival estimates with covariates*

Survival statistics	No. livebirths	Dead < 15 years	No. alive	% alive
Town	556	207	349	62.8
Lowlands	1,505	604	901	59.9
Highlands	1,015	529	486	47.9
	Chi-square	DF	Pr. Chi-square	
Wilcoxon	40.0	2	0.0001	
Log-rank	44.9	2	0.0001	
Association of responses with covariates				
Forward stepwise chi-square (Wilcoxon test)				
	Chi-square		Pr. Chi-square	Pr. increment
Vaccination	6.11		0.01	0.01
Delivery	9.22		0.01	0.08
Sex	10.45		0.01	0.27
Matrimony status	10.97		0.03	0.47
No. visits to medical center	11.31		0.04	0.55
Forward stepwise chi-square (log-rank test)				
	Chi-square		Pr. Chi-square	Pr. increment
Delivery	4.01		0.04	0.04
Vaccination	6.06		0.05	0.15
Sex	7.18		0.07	0.29
Matrimony status	7.82		0.10	0.42
No. visits to medical center	8.00		0.15	0.66

in parental care, is likely to cause the differences observed in the survival times.

In order to test the association between survival time and several variables reflecting environment and culture—marital status of the mother, conditions of delivery, child's sex, vaccinations received, and frequency of visits to a medical center—the overall chi-squares of the Wilcoxon and log-rank tests were computed through partial chi-square statistics following a forward stepwise approach (Table 6).

The two main variables associated with survival time are that of vaccinations and that of the conditions of delivery (i.e., whether delivery occurs at home with or without the help of a midwife, or within a medical environment): two covariates directly related with the child's health. The next highest-ranking variables, in descending order, are the child's sex, the mother's marital status, and the frequency of visits to a medical center. It is therefore not absurd to think that the discrepancies in survival times among the three groups could principally be caused by differences in primary environmental conditions (infectious diseases, sanitary context of delivery, sex differential morbidity), eventually mediated by sociocultural responses (vaccinations,

traditions about delivery, behavior related to child's sex). The marital status of the mother and the frequency of contacts with dispensaries (which are more oriented to the organization of preventive action than to supply of curative care) do not appear to be much implicated.

Finally, it appears that the two groups showing what could be "controlled" reproductive patterns exhibit a relative enhancement of offspring survival, in comparison with the third, supposedly "non-controlling" group, whatever its cause: either effectively better parental care or simply more favorable environmental conditions.

DISCUSSION

When considering the proportion among live born of children reaching the age of 15 years, the group most successful is clearly the one which shows the highest survival curve. The same is not necessarily true when reproductive success is considered in a purely evolutionary perspective—i.e., for its significance in terms of gene transmission. From this standpoint, the most successful are those who transfer the most copies of their genes, whatever the cost in miscarriages or children's deaths at any age below

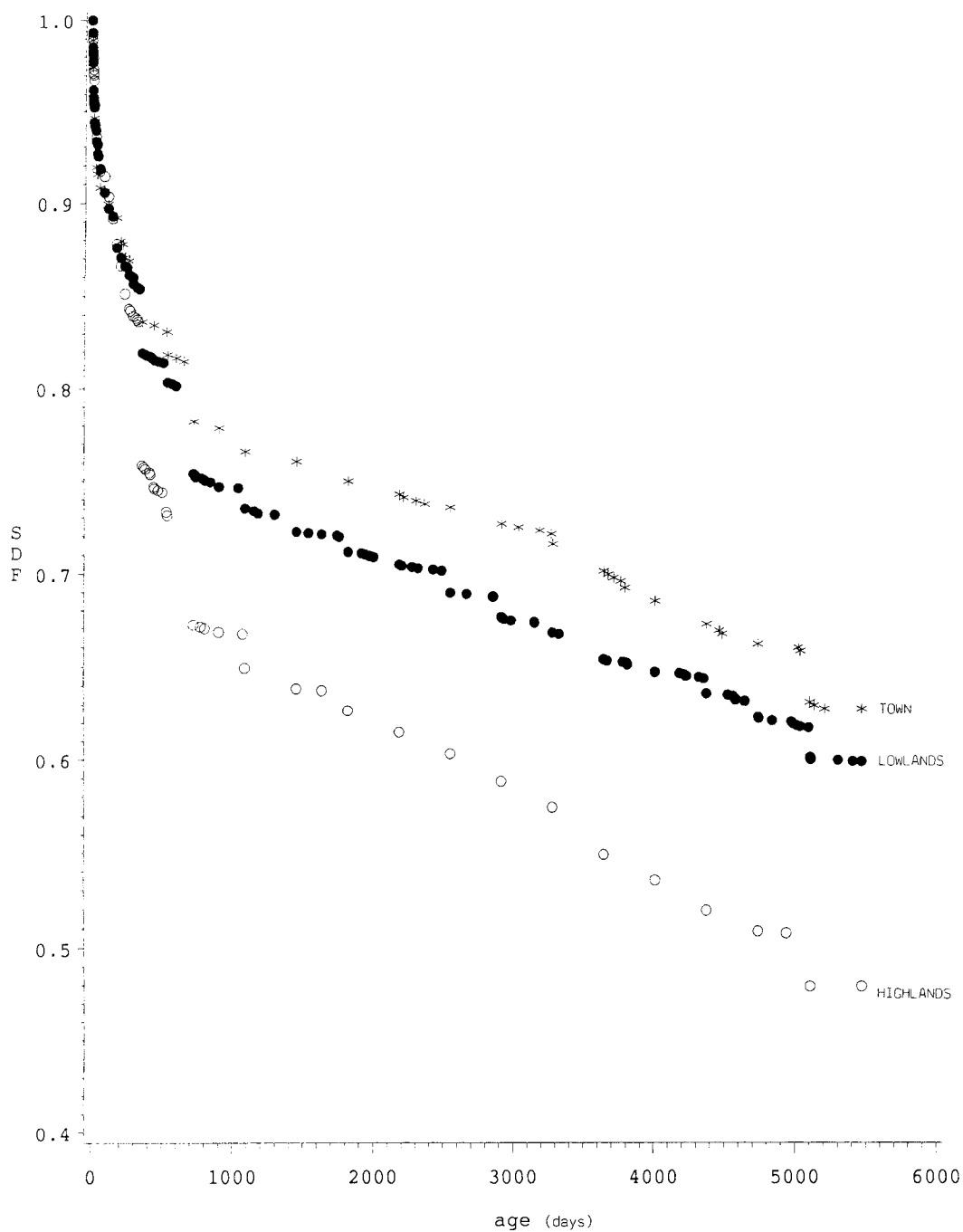


Fig. 2. Survival function estimates of the three groups. Each symbol—star, dot, or circle—stands for a deceased child.

15 years. The pertinent expression of reproductive success is then the crude number of children reaching 15 years (ENC), and this measure can lead to completely different results.

In the case of these Berber groups, if a linear regression of ENC is fitted on women's age in each sample and the mean ENC at mother's age of 60 years is determined (age at which any child born to a mother of 45 years and surviving, already reached his 15th birthday), the estimates are 5.5 children for the highlanders, 4.7 children for the town inhabitants, and 4.2 children for the villagers in the plain (Crognier, 1993). This would therefore mean that the longer reproductive span of the highlanders would compensate for their longer intervals between births and their more numerous reproductive failures. This strategy would allow them to finally obtain a larger number of offspring reaching the age of reproductive maturity than do the two other groups, if the frequency of sterility or that of women dying before the end of reproductive life is not higher. Although information related to frequencies of death before menopause is not available, estimations of primary sterility by the proportion of childless women and of secondary sterility by that of women ending their reproductive life before an arbitrary age of 30 years can be obtained. They show their lower incidence in the highlands (respectively, highlands 1.5% and 5%; town 2% and 10%; lowlands 6% and 16%), thus confirming their higher reproductive success.

These two evaluations of reproductive success refer to different frames. The first, which speculates about the efficiency of the reproductive process (input in live births compared with the output in mature offspring), relates it to "economic" references as if fertility were determined by the rational allocation of resources among competing wants. It belongs therefore to what Van Nort (1956) called "the economic model of fertility." The second, which considers only the relative proliferation of groups, refers to "biological fertility"—i.e., to the evolutionary processes of competing gene pools.

This lack of precision associated with the common use of "reproductive success" is further emphasized by the additional fact that,

from a Darwinian viewpoint, reproductive success is primarily success in gene transmission, which involves also offspring reproduction. Josephson's observation (1993) that the number of the offspring's progeny may be greater for women of low fertility and smaller for highly fertile women, depending on socioeconomic status and on the corollary quality of parental care, is an illustration of the need to consider reproductive success in a wider perspective. The observation of reproductive strategies, and their evaluation in terms of reproductive success, would therefore greatly benefit from a more complete observation of contributing factors, including the appraisal of the part of the parental generation either infertile or dying before having completed its reproduction, and that of offspring's own fertility.

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